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COMPARATIVE EMISSION ANALYSIS OF CNG AND OCTANE IN RETROFITTED CAR ENGINES

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ABSTRACT

Comparative emission analysis of octane and compressed natural gas (CNG) fueled retrofitted spark ignition car engine refers to exhaust emission (carbon mono-oxide, carbon di-oxide, Nitrogen Oxide) analysis and exhaust temperature on car engines which are operated with either gasoline or CNG using a solenoid actuated valve mechanism. The analysis was successfully carried out with the help of an exhaust gas analyzer (IMR 4000). Octane was used as the conventional fuels, whereas CNG was the alternative fuel. Comparative analysis of the experimental results showed the retrofitted engine produced higher exhaust gas temperature and NOx emission over different engines of different mileage when were used with CNG. Other emission contents were significantly lower than those of the gasoline emissions.

Key words: Exhaust temperature, NO_x, Knocking, CNG (Compressed Natural Gas).

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1. INTRODUCTION

Over the last few decades it has been observed that the number of automotive vehicles is increasing at a very high rate in most big cities globally. Around the world it is acknowledged that an alternative fuel to gasoline needed to be developed. Alternative fuels need to be used more for automobile use for their obvious emissions benefits, but also as a tool for a country to become less dependent on the oil imported. Although natural gas is a hugely available resource in some countries, it has not been widely accepted as an alternative fuel to gasoline. Although in some countries, it is extensively used as alternate fuel due to its lower price and availability. Hence, research has to be done to decide whether this is detrimental to the environment or we can count on CNG as alternative fuel. In this analysis, general exhaust gas analyzer is used which operates with the sampling system shown in Figure 01.

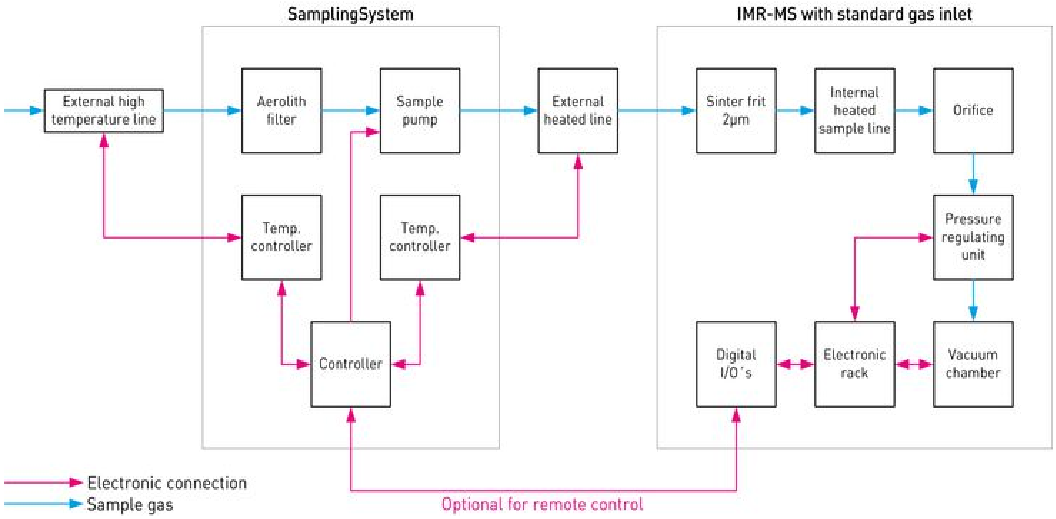

Figure 1 Block Diagram of Sampling System of gas analyzer

2. CNG AS AN ALTERNATIVE FUEL

CNG is a mixture of hydrocarbons in gaseous form, consists of approximately 80-90 % of methane along with some percentage of ethane, propane, nitrogen. The main source of CNG fuel are mainly underground reserves, it can also be made from agricultural waste, human waste and garbage. Thermodynamic properties of CNG are described in the Table, CNG has low energy density, and hence it is compressed to a pressure of 200 to 250 MPa to enhance the vehicle on-board energy storage. CNG is colorless, odorless, non-toxic, lighter than air and inflammable. The advantages of CNG compared to gasoline & diesel are as follows:

a) Unique combustion and suitable mixture formation properties.

b) Due to high octane number of CNG, engine operates smoothly with high compression ratios without knocking.

c) Higher flammability compared to gasoline that make it appropriate to run on lean burn technology will leads to lowering exhaust emissions and fuel operating cost.

d) CNG is safer, lighter, burns cleaner and dissipates quickly than most of the other fuel.

e) It ignites quickly, it ignites only when the gas to air ratio is between 5-15% by volume.

f) Because it is a clean burning fuel, engine durability is very high; it reduces the required maintenance of vehicle.

g) Also it does not mix up with the lubricants to dilute it or reduce its viscosity so that lubricant consumption is lower.

h) Higher self-spontaneous temperature makes it safer in case of leakage.

Both the SI and CI engines can be converted to run on CNG by using the Bi-fuel and duel fuel conversion kit respectively. Considering the advantages and suitability, CNG seems a very attractive and suitable option as alternate fuel.

The main drawback of CNG is its lower flame speed compared to gasoline. This lower flame speed causes the total combustion duration prolonged. It lacks latent heat of vaporization and has poor combustion stability.

Table 1

Properties	CNG
Formula	CH4
Stoichiometric ratio	17.2
Octane/Cetane number	120
Auto Ignition Temp °C	540
Higher heating value (MJ/kg)	49
Lower heating value (MJ/kg)	45.9
Density @ 25 °C (kg/m3)	2.52
Minimum Ignition Energy(MJ)	0.26
flame propagation speed(m/sec)	0.43
Adiabatic Flame Temp (K)	2266
Compression Ratio	9 to 12

3. EXPERIMENTAL SET UP

3.1. Equipment Used

The basic IMR 4000 exhaust gas analyzer was used to carry out this study. It uses electrochemical sensors for the gas components CO, NO. For the gases CO, CO_2 and CxHy NDIR (non-dispersive infrared absorption) sensors are used. We have measured the values of exhaust gases using both gasoline and CNG at same RPM in different car engines.

Figure 2 IMR 4000

3.2. Detail Specification

Table 2 Technical Data-sheet of IMR 4000

Component	Method	smallest measuring range	largest measuring range	resolution	accuracy
O2 (Oxygen)	Electro chemical Sensor	0 ... 20,95 Vol.-%	0 ... 20,95 Vol.-%	0,01 Vol.-%	+/- 0,2 %
CO (Carbon monoxide)		0 ... 75 mg/m³	0 ... 5 Vol.-%	< 100 mg/m³: 0,1 mg > 100 mg/m³: 1,0 mg	max. +/- 3 % from end of measuring range
NO (Nitric oxide)		0 ... 200 mg/m³	0 ... 5.000 mg/m³		
NO_2 (Nitric dioxide)*		0 ... 100 mg/m³	0 ... 500 mg/m³		
SO_2 (Sulfur dioxide)*		0 ... 75 mg/m³	0 ... 5.000 mg/m³		
H_2S (Hydrogen sulfide)*		0 ... 60 mg/m³	0 ... 300 mg/m³		+/- 3%
H_2 (Hydrogen)*	TCD	0 ... 20 Vol.-%	0 ... 100 Vol.-%		+/- 3%
O_2 (Oxygen)*	Paramagnetic Sensor	0 ... 20,95 Vol.-%	0 ... 100 Vol.-%	0,01 Vol.-%	+/- 0,2 %
CH_4 (Methane)*	Infrared Sensor	0 ... 0,2 Vol.-%	0 ... 100 Vol.-%	0,1 Vol.-%	+/- 2 %
CO_2 (Carbon dioxide)*		0 ... 20 Vol.-%	0 ... 100 Vol.-%		
NO (Nitric oxide) *		0 ... 2000 mg/m³	0 ... 5 Vol.-%		
SO_2 (Sulfur dioxide)*		0 ... 2000 mg/m³	0 ... 5 Vol.-%		
CO (Carbon monoxide)*		0 ... 2000 mg/m³	0 ... 100 Vol.-%		
C_xH_y (Hydro carbons)* (< LEL)	Pelistor sensor	0 ... 4,4 Vol.-% CH_4		10 ppm	< 10%
°C (Flue gas temperature)	Thermo couple NiCr-Ni	0 ... 500 °C	0 ... 1.605 °C	1 K	+/- 1 K
°C (Ambient air temperature)		- 20 ... 120 °C	- 20 ... 120 °C	1 K	+/- 1 K
hPa Draft / Pressure*	Semiconductor sensor	+/- 20 hPa (mm H_2O)	+/- 300 hPa (mm H_2O)	0,01	+/- 2,0 %
CO_2 (Carbon dioxide)**	Calculated	0 ... $CO_{2\ max.}$ ***		0,1 Vol.-%	+/- 0,2%
λ (Excess Air)		1,0 ... 99,9		0,01	+/- 2,0%
qA (Flue gas losses)		0 ... 99,9%		0,01	+/- 0,5%
ETA (Efficiency)		0 ... 99,9%		0,01	
v (Flue gas velocity)*	Semiconductor sensor	0 ... 5 m/s	0 ... 25 m/s	0,001 m/s	+/- 2,0%
Soot (Soot number)*	Filter paper method according DIN 51402	Volume - regulated suction pump 1,63 l/min ± 0,07 l/min			
The analyzer complies with EN 50379-2 / TÜV approved					

4. EXPERIMENTAL DATA TABULATION

Table 3 Experimental Data for random sample retrofitted car engines

Sample	Fuel Used	Temp Gas (°C)	CO_2 (%)	CO ppm	NO ppm
1	OCT	54	10.15	229	5
	CNG	70	9.14	93	20
2	OCT	172	9.76	173	28
	CNG	176	8.03	59	186
3	OCT	73	8.19	1555	13
	CNG	89	7.5	349	102
4	OCT	58	10.56	1924	6

	CNG	60	9.68	525	90
5	OCT	111	9.99	1973	182
	CNG	136	8.36	542	299
6	OCT	98	9.21	1521	235
	CNG	101	3.73	763	350
7	OCT	98	7.95	522	211
	CNG	105	6.83	122	314
8	OCT	146	9.80	429	232
	CNG	160	8.25	102	342
9	OCT	51	8.17	1603	42
	CNG	62	5.39	302	130

5. EMISSIONS CHARACTERISTICS

The HC. CO, CO_2 emissions from CNG fueled engines are less than that of gasoline engines. Theoretically, these emissions from CNG fueled engine should be lower due to the gaseous form which gives an excellent mixing and less carbon CH_4 for CNG as compared to that of C_8-C_{18} for Octane.

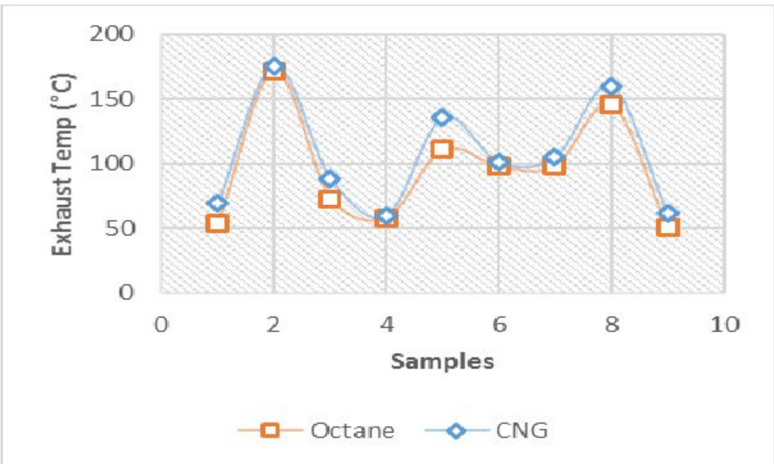

Figure 3 Graph of Exhaust Temperature for different samples

5.1. Carbon Mono-Oxide

Carbon monoxide is product of incomplete combustion of fuel. Formation of carbon mono-oxide indicates loss of power result of oxygen deficiency in combustion chamber. The CO emission of the CNG was significantly lower than that of the gasoline for all samples irrespective of usage (how old the engine is).

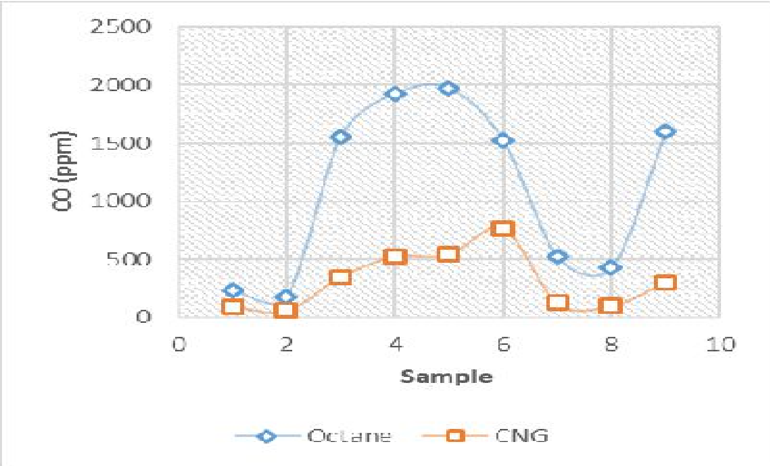

Figure 4 CO Emission for different samples

The graph shows CO emissions for CNG are lower than Octane. In some cases, (sample no 3-6) the carbon mono-oxide shows increasing trend may be due to less reaction time for more fuel supplied. Higher combustion temperatures is another reason of the low CO emission of the CNG fueled engine. At high combustion temperatures, the CO get converts to CO_2 during combustion.

5.2 Carbon Di-Oxide

The composition of gas showed that the CNG consists mostly of methane (CH_4) whereas the gasoline (C_8H_{18}) compound packed less hydrogen per carbon. Thus, the percentage of carbon in the methane, i.e., the CNG was lower than that of the octane. This led to the lower emission of CO_2 for the CNG than the octane.

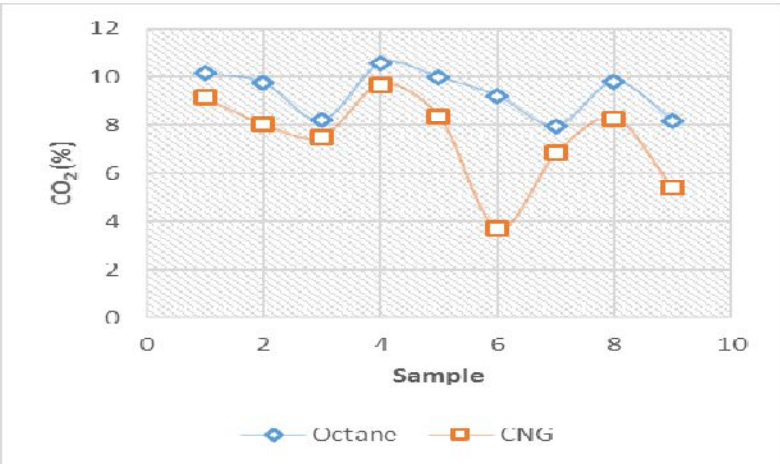

Figure 5 CO_2 Emission for different samples

The emissions of CO_2 decrease with the decrease in the loading, which may be the reason of rapid CO_2 drop for sample 6. Gasoline shows almost the higher percentage of CO_2 emissions for all the sample. As already explained for CNG, CO_2 emissions obtained are lower as compared to gasoline as shown in figure 5.

5.3. Nitrogen Mono-Oxide

Nitrogen oxides are generated from oxygen and nitrogen under high pressure and temperature conditions in the engine cylinder. The NO_x emissions are strongly influenced by the lean fuel with high cylinder temperatures or high peak combustion temperature. A fuel with high heat release rate at premix or rapid combustion phase and lower heat release rate at mixing controlled combustion phase would produce the NO_X.

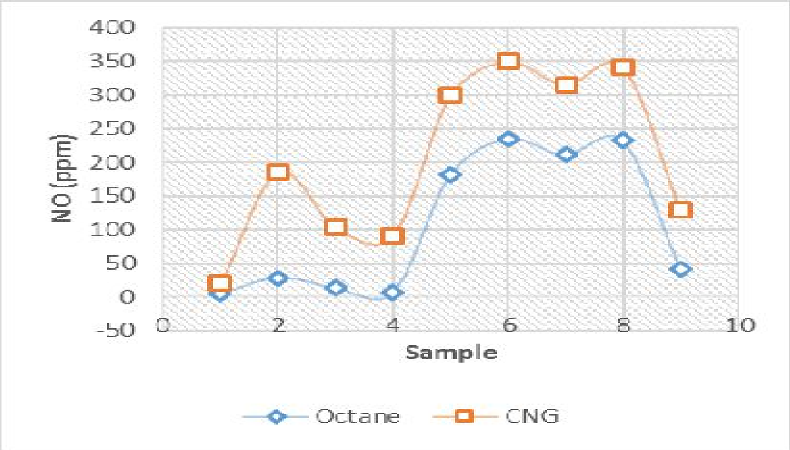

Figure 6 NO emission for different samples

The value of the NOx increases with the compression ratio as well as loading, the graph shows that NOx obtained for CNG is higher than that of gasoline. Higher exhaust temperature with increase in compression ratio are favorable for emission of NOx which is the cause for sample 2 and, further increase in load causes significant temperature rise, thus result of which shows value of NOx reaches high at sample 5 to 8.

6. CONCLUSION

In this paper, it was attempted to understand the emission characteristics specially focusing on the cases of retrofitted engines. CNG is attractive for five reasons. It is the only fuel cheaper than gasoline or diesel. It has inherently lower air pollution emissions. It has lower greenhouse gas emissions. Its use extends petroleum supplies, and there are large quantities of the fuel available in the world. There are several major problems needed to be solved when using natural gas engines, there is the set point for the best compromise between emissions and fuel economy is not clear, the optimum air–fuel ratio changes with both operating conditions and fuel properties.

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